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AIRCRAFT ARMAMENTS, Inc.

FINAL COMPREHENSIVE REPORT

INVESTIGATION OF TELECARTRIDGE DISSEMINATION TECHNIQUES

CONTRACT NO. DA-18-108-AMC-80(A)
CP 3-9800

ER-3043C
REPORT NO.

February 1964
DATE

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FINAL COMPREHENSIVE REPORT

For the Period of 1 January 1963 through 29 February 1964

Contract No. DA18-108-AMC-80(A) CP3-9800

I. INTRODUCTION

This is the last in a series of progress reports to be submitted under the terms of contract No. DA18-108-AMC-80(A) CP3-9800.

II. RESUME OF ACCOMPLISHMENTS

During the period of investigation of this contract, tests were conducted at both the Aircraft Armaments, Inc. and the Army Chemical Center test facilities to evaluate different methods of disseminating various selected simulants by means of a Telecartridge cup sealed dispenser.

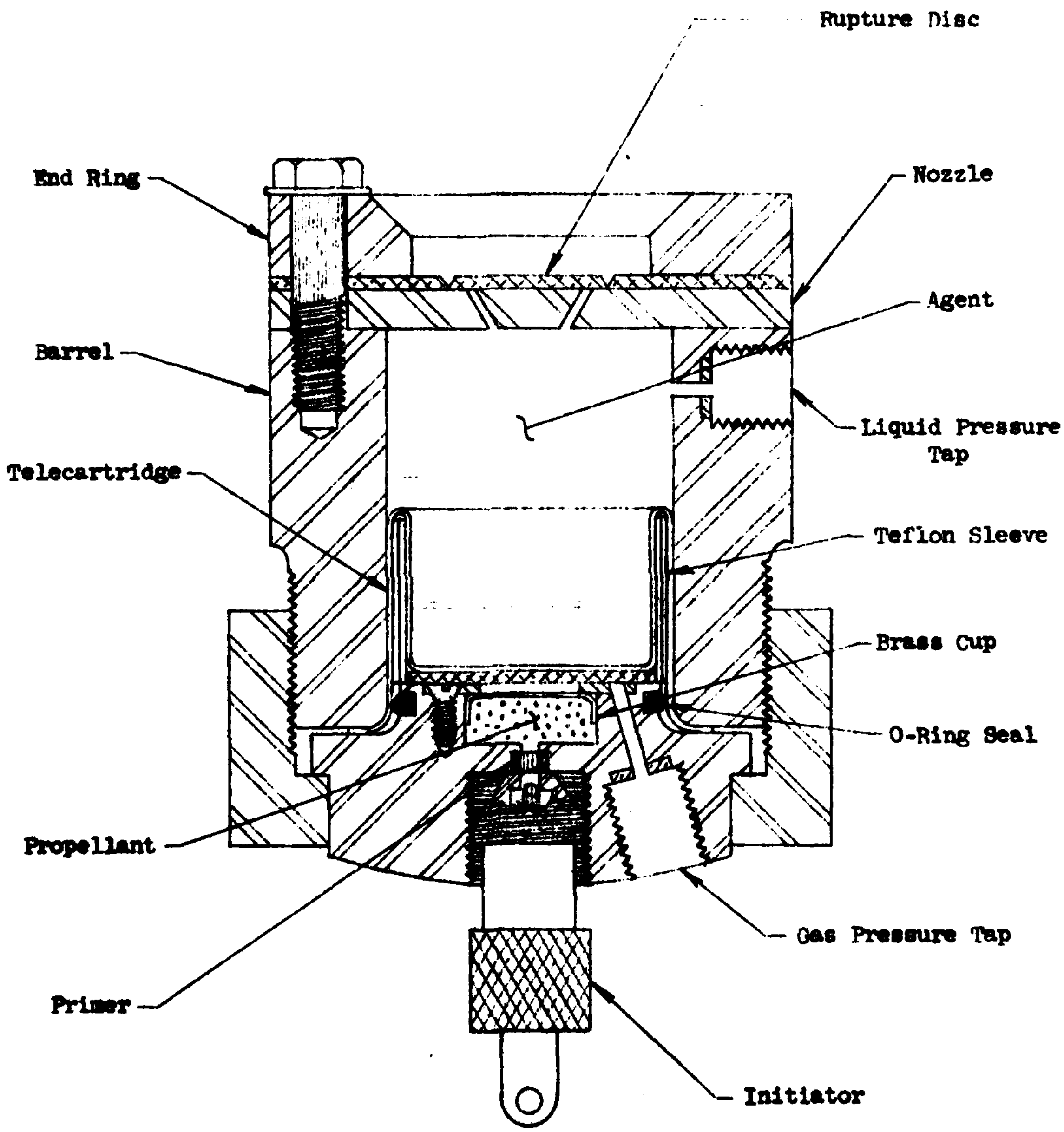
The initial task to be carried out was broken down into three stages. The first stage consisted of the design of a dissemination test fixture. The second stage involved the acquisition of the necessary hardware. The third stage consisted of the development of propellant charges and nozzle configurations to produce various pressure ranges corresponding to the different configurations of telecartridge dispensers.

During January of 1963, an existing 40 millimeter test fixture was modified to use the latest designs of dissemination nozzles.

On January 24, 1963, this fixture along with hardware for both liquid and powder dissemination was delivered to H. Rosen at the Army Chemical Center.

Throughout the early months of the contract, another existing fixture for use with telecartridge dispensers was modified and used in the testing of nozzles and other variables and the gathering of data.

The first tests were conducted at Aircraft Armaments, Inc. using water as the simulant. At this time development was begun on each of several different nozzles which were felt to be capable of producing small aerosol particles in the range of 10 microns (MMD). Figure 1 is a layout of the first test fixture with the 6-hole nozzle. Each of these nozzles was then



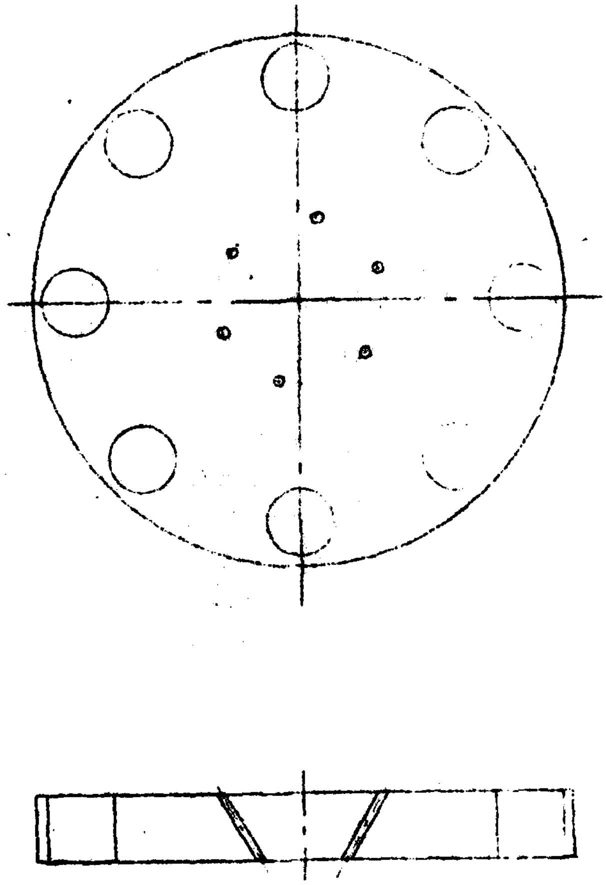
PRESSURE TEST FIXTURE

Figure 1

proof tested at the Aircraft Armaments, Inc. test facilities under varying conditions of simulant and powder charge. After a series of successful shots in each category, the unit was taken to the Army Chemical Center's test facilities for tests to measure the unit's dissemination characteristics.

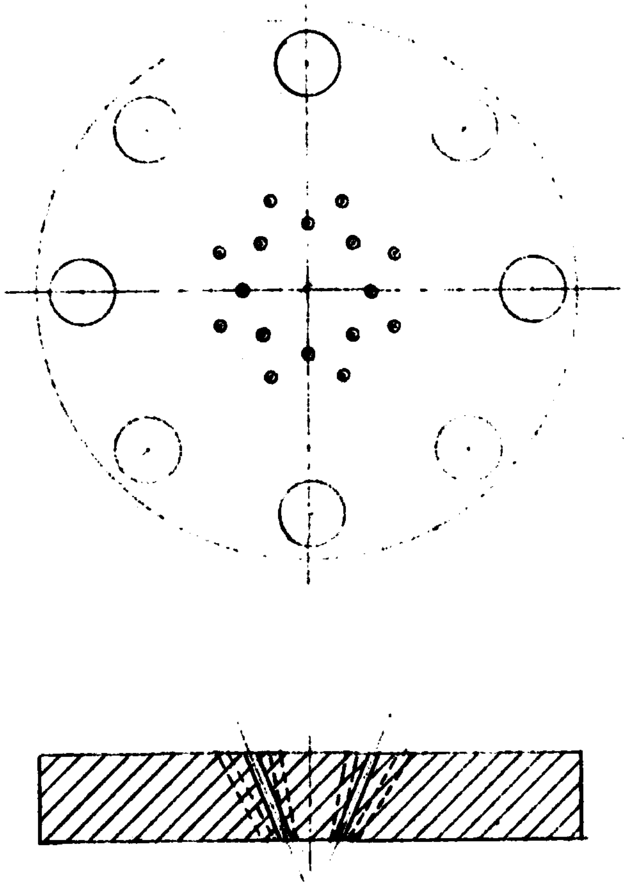
During this period there were three nozzle configurations tested. These included: (1) a 6-hole nozzle with one-sixteenth inch diameter holes, (2) a 16-hole nozzle with .039 inch diameter holes and (3) a 92-hole nozzle with .016 inch diameter holes. A schematic of each of these nozzles is shown in Figures 2, 3 and 4, repsectively. These nozzles were tested using propellant charges of 20, 30 and 40 grains of IMR 5010 propellant with 10 percent by weight of AR-4 Black Powder as a booster. These charges produced peak pressures of approximately 5,200 psi, 7,800 psi and 10,800 psi, respectively. The tests conducted during this phase were made with each of three different simulants. The three simulants used were (1) Dimethyl Hydrogen Phosphite (DMHP), (2) varying concentrations of egg albumin in carbon tetrachloride in slurry form and (3) BIS (2 ethylhexyl) Hydrogen Phosphite.

Also during this period, a method was devised and tested at the Aircraft Armaments, Inc. test facilities to disseminate dry powders. The method consisted of using a pusher rod supported between a pusher disc and the rupture disc. When the propellant was fired, the rod broke the rupture disc before any packing of the powder took place. Several tests were conducted in which the unit functioned properly but it was decided that this method of dissemination would not produce particles of a satisfactory size so no further tests were made with this apparatus.



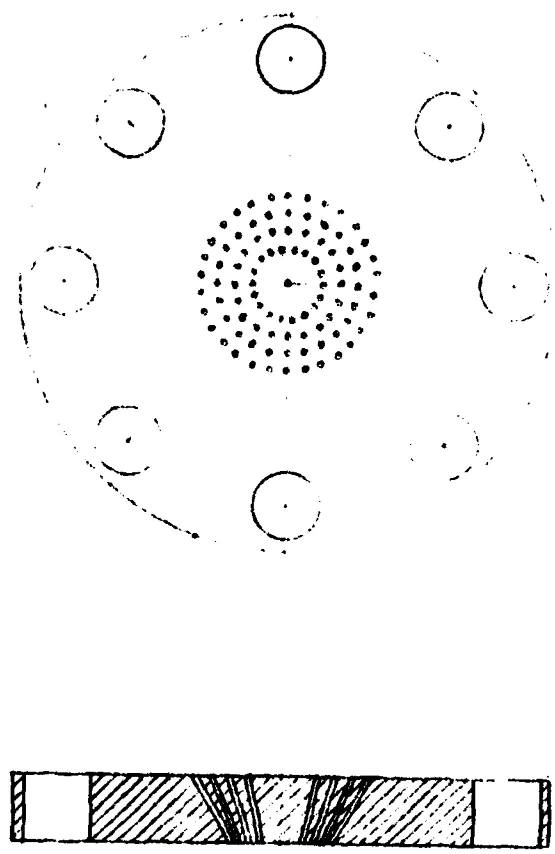
NOZZLE WITH 6 (1/16" dia.) HOLES

FIGURE 2



Nozzle with 16 (.039 dia.) Holes

FIGURE 3



Nozzle with 92 (1/64" dia.) Holes

FIGURE 4

During this period it was decided to adopt a new method of tele-cartridge disseminator function. This change was directed toward a more positive functioning unit for powders and slurries based on current development work on other programs at Aircraft Armaments, Inc.

While existing hardware was being modified to facilitate this change, certain studies were made which led to further changes in the test fixture. The main change was the decision to design and build a new test fixture capable of being fired with peak pressures of 35,000 psi. The decision to use these pressures, which necessitated the design of the new test fixture, came about through data gathered from an article in the American Rocket Society Journal, April 1959, page 256. This article dealt with the study of producing small aerosol particles by injecting a fluid stream into a moving air stream. Although this was not the same situation we were involved in, it was felt that this data could be used to gain aerosol particles in the range of 10 microns (MMD) decided necessary for good percentages of fill-airborne for non-volatile simulants. In the report is a graph of data collected which is a plot of relative air velocity against the mean particle size obtained and the pressure required to produce such velocities. Using 10 microns (MMD) as the desired result and entering the graph it was found that a relative air velocity of about 1,680 feet per second was required. Further interpolation showed that a pressure of about 19,000 psi was needed to obtain such velocities. After making an estimate of the possible difference between the two methods of injection, it was decided that the unit would be fired with peak pressures of approximately 35,000 psi.

These higher peak pressures also necessitated a change to nickel cups from aluminum for their added strength. Also at this time new hardware to go with these cups was designed and fabricated.

While awaiting the delivery of the nickel cups, additional tests with the high pressure test fixture were made up to peak pressures of about 20,000 psi to check the units function.

Also at this time computations were made to find the amount of propellant charge necessary to produce the desired working pressures. The equation used was:

$$* \; C = \frac{PV}{F \times 12}$$

where:
C = charge weight - lbs.
P = peak pressure - lbs-in^2
V = initial volume - in^3
F = constant based on the propellant used - ft-lbs/lb

Substituting:

$$C = \frac{35000 \times 3.12}{330000 \times 12}$$

$$C = .0275 \text{ lbs.}$$

$$\frac{1}{453.6} = \frac{.0275}{C_1}$$

$$C_1 = 12.50 \text{ grams}$$

$$C_1 = 12.50 \times 15.43$$

$$C_1 = 193 \text{ grains}$$

* Warren, Francis A., Rocket Propellants, p. 73-76, New York, Reinhold Publishing Corporation, 1958

For the standard cup this figure compared favorably with an actual charge of about 215 grains needed to obtain peak pressures of 35,000 psi. Variations of the propellant constants shows that for a given charge, the peak pressure can be adjusted by varying the type of propellant and the web size.

In addition, computations were made based on decay curves from which particle sizes may be directly determined at any time interval for particles falling from a given height. Calculations below were made using the Army Chemical Center's test chamber. The basic formula is:

* $V = KSD^2$

where: V = velocity - ft/min

K = .0059 for a sphere in air

S = specific gravity of droplet (assume water = 1)

D = diameter of droplet in microns

Substituting: $\frac{S}{t}$ for V, we have

$$\frac{4.5}{t} = KSD^2$$

$$t = \frac{4.5}{.0059 \times 1 \times 10^2}$$

$$t = 7.62 \text{ minutes}$$

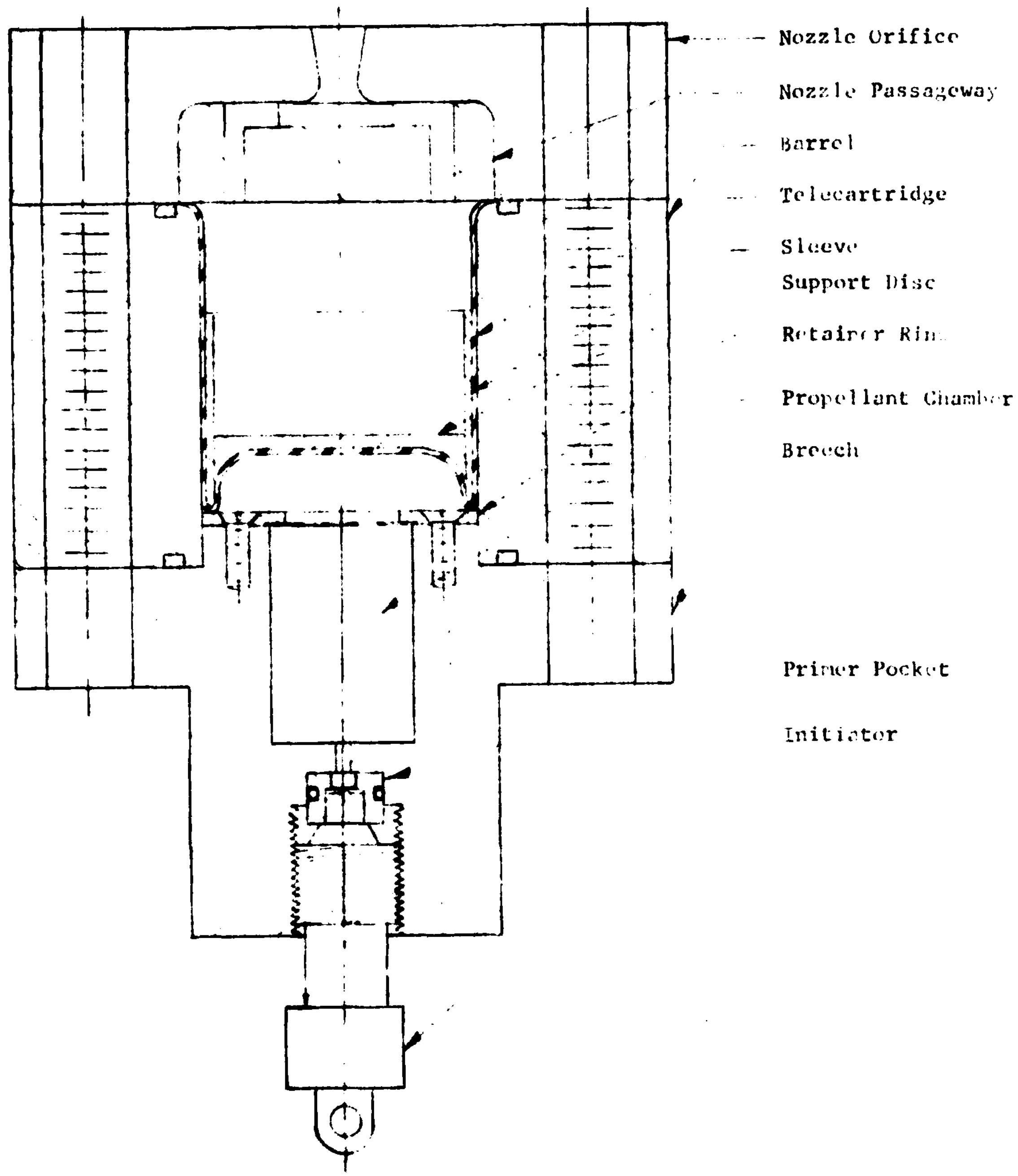
In addition to the above calculations, an analysis was made to predict the particle size distribution for a particular test shot for comparison with results from the Army Chemical Center. This analysis involved taking a typical time-pressure curve and interpolating from a curve, drawn from the American Rocket Society

* Hix, C.F., Jr. Alley, R.P., Physical Laws and Effects, p. 203, John Wiley & Sons, Inc., New York, 1958.

Journal, to obtain the relative stream velocity corresponding to each point on the pressure curve. From this it was possible to perform an integration over the velocity curve to obtain a particle size distribution related to the various points on the velocity curve.

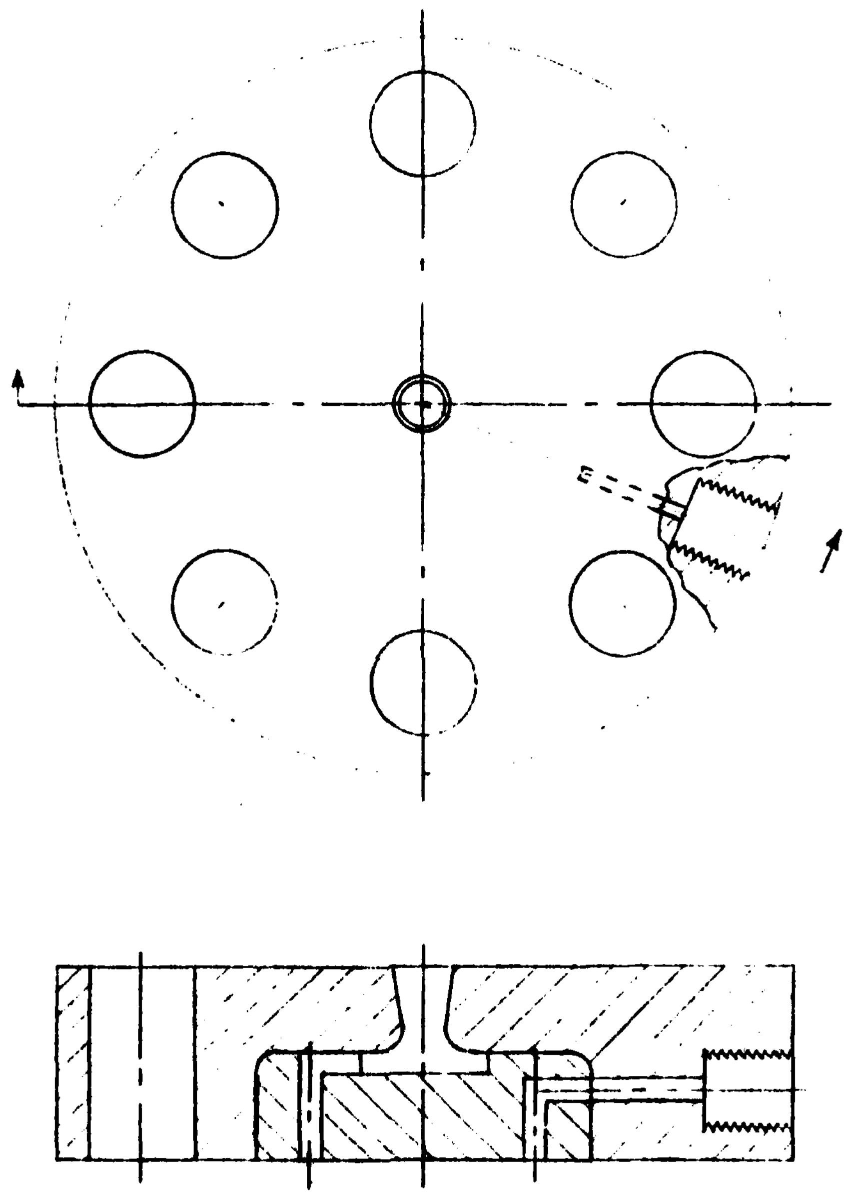
A layout of the new high pressure test fixture with the venturi orifice nozzle and standard Telecartridge dispenser is illustrated in Figure 5. To be tested at high pressures, in addition to the nozzle designs already produced, was a new type of nozzle using a venturi orifice shown in Figure 6. This nozzle incorporated the venturi feature in order to gain some diffusion effect to help in breaking up the stream into finer aerosol particles. In the operation of this nozzle, the fluid is first forced through one of four passageways and then into a swirl chamber. From here it is forced through the venturi into the surrounding air. After developing the propellant charge to produce the desired flow rate, this unit was taken to the Army Chemical Center for tests of its dissemination characteristics. High speed motion pictures were also taken of the unit at Aircraft Armaments, Inc. Comparison of results from both sources indicates the failure of the unit to perform as expected was due to a lower discharge coefficient, through the passageways, than expected. This effect caused a large percentage of the fluid to be emitted at a much lower velocity than that required to produce the desired particle sizes. Much of this slower fluid simply fell in large droplets on the floor in front of the unit.

The next nozzle tested under the same conditions of peak pressure was a 16-hole nozzle with one-sixteenth in diameter holes shown in Figure 7. An analysis of tests and movies of this nozzle seemed to indicate that its failure to produce particles of the desired size was due to an interaction of particles.



HIGH PRESSURE TEST FIXTURE

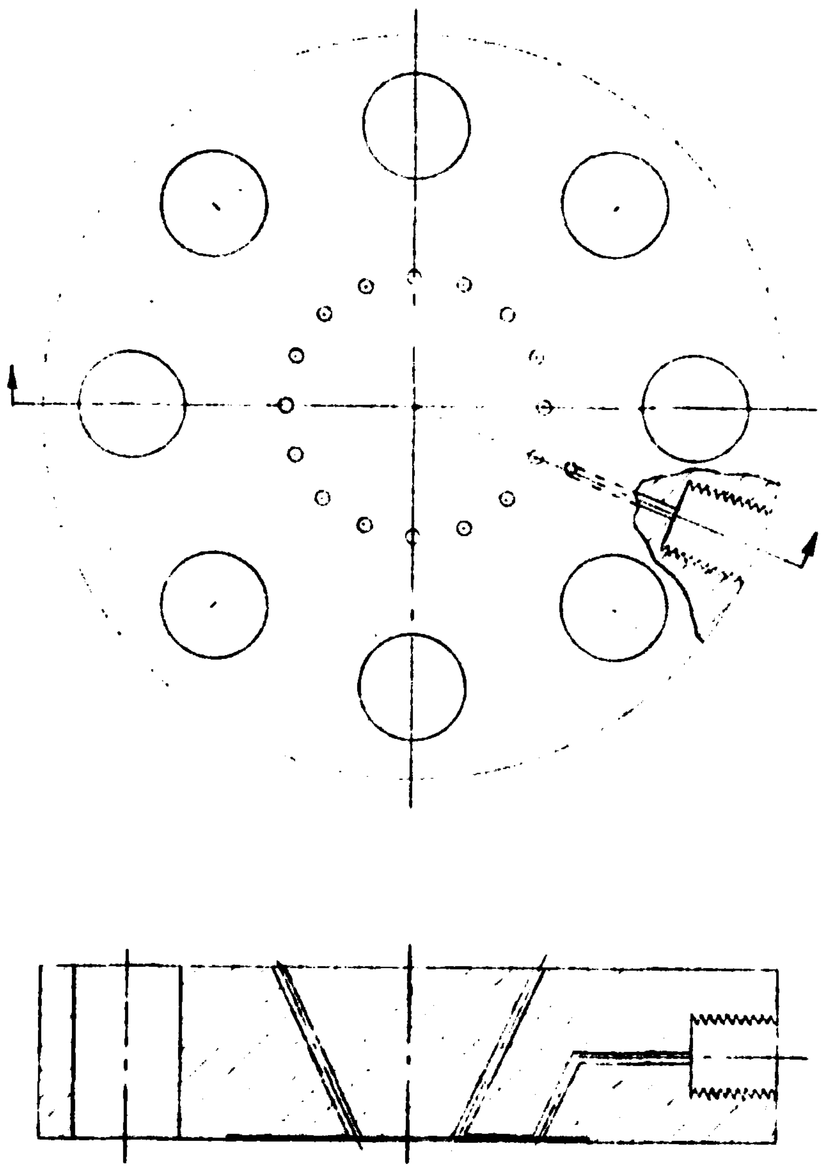
FIGURE 5



NOZZLE WITH VENTURI ORIFICE

FIGURE 6

AIRCRAFT ARMAMENTS, Inc.



NOZZLE WITH 16 (.0625 dia.) HOLES

FIGURE 7

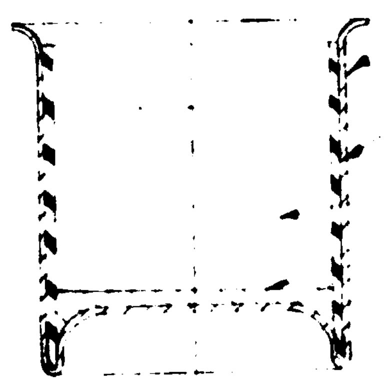
It appeared in the films that after the initial streams of fluid had come in contact with the still air in front of the nozzle they were slowed down considerably. However, ensuing particles are entering a moving atmosphere, caused by preceeding particles, and, therefore, travel at higher velocities. These later particles then overtake the initial particles and are then in a position to recombine to form larger particles.

These results led to a modification consisting of inserting a plug in the Telecartridge dispenser to decrease the actual simulant volume by about one-fifth of its original volume. Figure 8 shows the Telecartridge dispenser configuration used for this unit. It was felt that this change would allow the first streams to mix with the air and form small particles with a minimum amount of fluid following to recombine into larger particles. This unit was then tested at the Army Chemical Center facilities to measure its dissemination characteristics. The results of the tests showed the particle sizes of the droplets picked up on the fall out slides to be smaller than those of any previous tests. However, results of tests on percent fill-airborne were no better than previous tests. These poor results may have been caused by the fact that the volume of simulant disseminated was small enough that it was near or below the vapor concentration that can be effectively assessed by this type of sampling technique.

The next unit tested consisted of a Telecartridge dispenser filled approximately three-quarters full of a dry simulant powder (egg albumin). The unit was then sealed by a rupture disc with a threaded extension to accept a mini-check valve. The unit was then loaded with nitrogen gas to an internal pressure of about 450 psi. When the unit is fired a sleeve inside the Telecartridge actuator breaks the rupture disc allowing the nitrogen to escape carrying the albumin with it before any packing action occurs. Tests at Aircraft Armaments, Inc. looked very good with the amount of residue in the unit being negligable as compared to slurry shots where the albumin was packed into the areas around the flange of the Telecartridge cup seal and the sleeve. However, the actual test shot at the Army Chemical Center contained only 200 psi of nitrogen. An illustration of the Telecartridge cup seal configuration for this shot is shown in Figure 9.

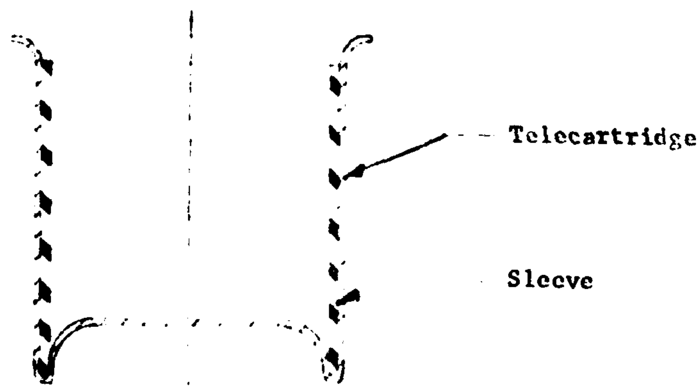
The last nozzle constructed for testing was a flat plate with a single .010 inch diameter hole, shown in Figure 10. Preliminary shots at Aircraft Armaments, Inc. functioned properly with indications that the cloud produced was tall and thin. However, as the propellant charge was increased to obtain higher peak pressures near 35,000 psi, a problem of sealing the unit was developed. Because of the difficulties encountered and the short time remaining on the contract, further testing of this configuration was halted for lack of time to design and fabricate the necessary hardware to seal the unit. The layout of the Telecartridge cup seal configuration for this type of shot is given in Figure 11.

A table has been set up in Figure 12 which lists each of the shots fired at the Army Chemical Center and gives data on the variables involved in the tests. Also tabulated is the percent fill-airborne for each shot corresponding to particles of 10, 25, 50 and 100 microns (MMD). The percentages have been left out for DMMP, however, for particles of 50 and 100 microns (MMD) because of volatile simulants at these short times.



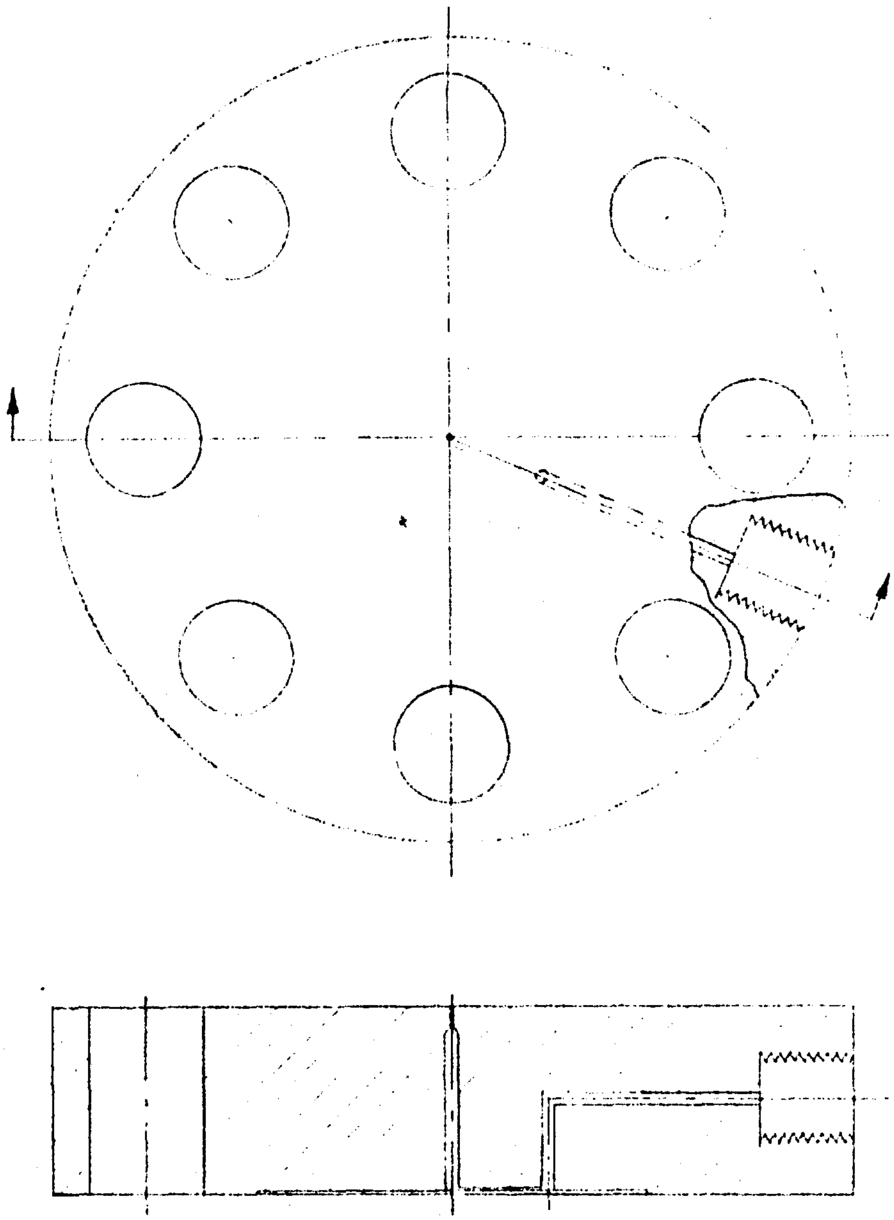
LOW CAPACITY TELECARTRIDGE

FIGURE 8



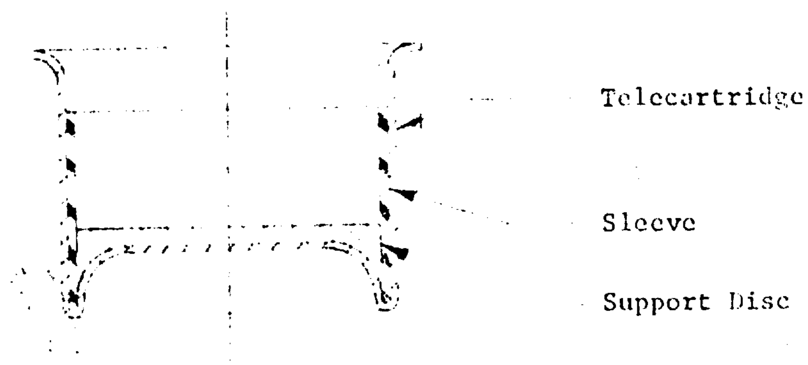
DRY POWDER TELECARTRIDGE

FIGURE 9



NOZZLE WITH 1 (.010 dia.) HOLE

FIGURE 10



.010 HOLE NOZZLE TELECARTRIDGE

FIGURE 11

Run No.	Charge grains	Max. Peak Pressure (psi)	Simulant	Nozzle
633	35	9,550	DMHP	6 - .0625" Dia. Holes
634	37	10,200	DMHP	6 - .0625" Dia. Holes
635	40	10,800	DMHP	6 - .0625" Dia. Holes
636	30	7,800	DMHP	6 - .0625" Dia. Holes
637	20	5,200	DMHP	6 - .0625" Dia. Holes
643	20	5,200	DMHP	6 - .0625" Dia. Holes
644	30	7,800	DMHP	6 - .0625" Dia. Holes
645	40	10,800	DMHP	6 - .0625" Dia. Holes
646	20	5,200	DMHP	16 - .039" Dia. Holes
648	40	10,800	DMHP	16 - .039" Dia. Holes
209	20	5,200	20% Egg Albumin	16 - .039" Dia. Holes
210	30	7,800	20% Egg Albumin	16 - .039" Dia. Holes
211	30	7,800	20% Egg Albumin	16 - .039" Dia. Holes
218	30	7,800	10% Egg Albumin	16 - .039" Dia. Holes
220	30	7,800	30% Egg Albumin	16 - .039" Dia. Holes
224	20	5,200	10% Egg Albumin	16 - .039" Dia. Holes
225	20	5,200	15% Egg Albumin	16 - .039" Dia. Holes
251	30	7,800	15% Egg Albumin	16 - .039" Dia. Holes
252	20	5,200	30% Egg Albumin	16 - .039" Dia. Holes
253	30	7,800	20% Egg Albumin	16 - .039" Dia. Holes
649	20	5,200	BIS	92 - .016" Dia. Holes
650	30	7,800	BIS	92 - .016" Dia. Holes
672	185	35,000	BIS	Venturi Orifice
673	185	35,000	BIS	Venturi Orifice
674	220	35,000	BIS	16 - .0625" Dia. Holes
675	220	35,000	BIS	16 - .0625" Dia. Holes
675	170	35,000	BIS (low capacity)	16 - .0625" Dia. Holes
371	30 B.P.		Egg Albumin	--------

TABULATION OF DATA FROM ACC TEST

FIGURE 12

t	Nozzle	% Fill 10 Microns	% Fill 25 Microns	% Fill 50 Microns	% Fill 100 Microns
	6 - .0625" Dia. Holes	44.0	15.4		
	6 - .0625" Dia. Holes	44.6	28.1		
	6 - .0625" Dia. Holes	52.0	30.8		
	6 - .0625" Dia. Holes	42.5	17.1		
	6 - .0625" Dia. Holes	48.4	20.4		
	6 - .0625" Dia. Holes	40.0	52.2		
	6 - .0625" Dia. Holes	45.2	60.0		
	6 - .0625" Dia. Holes	60.2	54.4		
	16 - .039" Dia. Holes	47.8	32.2		
	16 - .039" Dia. Holes	48.1	46.9		
n	16 - .039" Dia. Holes	11.9	15.1	16.9	17.1
n	16 - .039" Dia. Holes	8.2	18.2	25.0	29.2
n	16 - .039" Dia. Holes	8.0	28.4	38.1	43.0
n	16 - .039" Dia. Holes	13.2	58.0	75.3	85.7
n	16 - .039" Dia. Holes	1.8	11.0	14.3	15.0
n	16 - .039" Dia. Holes	9.1	15.0	17.3	18.1
n	16 - .039" Dia. Holes	5.1	12.0	12.1	12.1
n	16 - .039" Dia. Holes	3.9	24.1	35.6	42.0
n	16 - .039" Dia. Holes	1.1	6.0	7.2	7.5
n	16 - .039" Dia. Holes	2.3	11.5	15.0	16.1
	92 - .016" Dia. Holes	1.3	5.2	7.1	7.8
	92 - .016" Dia. Holes	1.3	7.1	11.0	12.0
	Venturi Orifice	1.2	15.5	22.0	24.1
	Venturi Orifice	1.4	21.1	33.0	39.0
	16 - .0625" Dia. Holes	1.0	41.1	70.0	83.0
	16 - .0625" Dia. Holes	11.1	39.0	50.0	53.5
ity)	16 - .0625" Dia. Holes	4.1	29.2	76.0	92.0
	- - - - - - - -	14.8	62.7		

TABULATION OF DATA FROM ACC TESTS

FIGURE 12

2

III. RESULTS

After establishing the time-pressure curve relationships for a particular unit configuration, a series of tests was scheduled at the Army Chemical Center test facilities.

The first such series was made using a nozzle drilled with 6 holes one-sixteenth of an inch in diameter. The simulant tested in this series was Dimethyl Hydrogen Phosphite (DMHP). The powder charges used were 20 grains, 30 grains, and 40 grains of IMR 5010 propellant. Included with these charges as in all shots was 10 percent by weight of AR-4 Black Powder as an igniter. Figure 13 lists the data for this series corresponding to the curves in Figure 14. The curves represent a plot of the percent fill-airborne against time. In each case an increase in charge of 10 grains produced an increase in percent fill-airborne of approximately 15 percent at each time interval.

The next two shots involved testing DMHP in the unit with the 16-hole nozzle. Data in Figure 15 for a 20 and 40 grain charge is plotted in Figure 16. These tests at peak pressures corresponding to the previous series did produce percent fills-airborne significantly better than the 6-hole nozzle.

The following two series of shots were made with egg albumin in a slurry with carbon tetrachloride in varying percentages. The nozzle used in both series was again the 16 hole nozzle. Data for the first series made with 30 grains of IMR 5010 propellant is given in Figure 17. The slurries in this series contained 10, 20 and 30 percent egg albumin in carbon tetrachloride, by weight. Figure 18, containing the plots of these three shots, shows an average increase in percent fill-airborne of 75 percent for each 10 percent decrease in egg albumin concentration.

Run No:	643	644	645
Charge (grains):	20	30	40
Simulant:	DMHP	DMHP	DMHP
Nozzle:	6 - 1/16" holes	6 - 1/16" holes	6 - 1/16" holes
Peak Pressure (psi):	5,200	7,800	10,800
<u>Time</u>			
1-1/2	51.0	60.0	53.8
2-1/2	42.3	43.3	52.4
4-1/2	42.7	46.9	54.7
6-1/2	37.3	47.8	52.2
8-1/2	42.8	48.3	53.7
10-1/2	46.1	46.4	66.3
12-1/2	43.1	43.7	65.7
14-1/2	42.4	46.2	49.5

COMPARATIVE TEST DATA

CORRESPONDS TO CURVES ON FIGURE 14

FIGURE 13

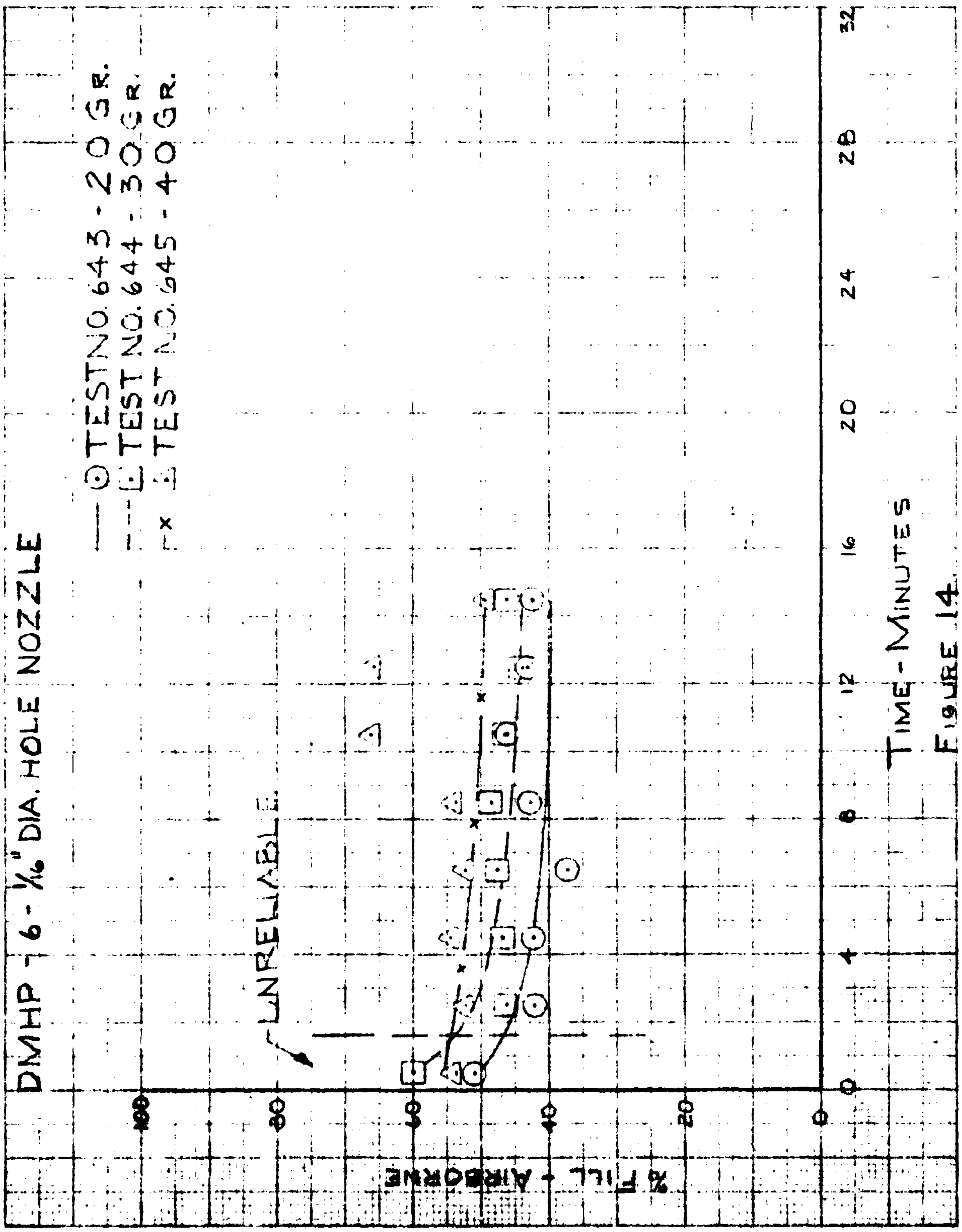

DMHP - 6 - 1/16" DIA. HOLE NOZZLE
TEST NO. 643 - 20 GR.
TEST NO. 644 - 30 GR.
TEST NO. 645 - 40 GR.
UNRELIABLE
% FILL - AIRBORNE
100
80
60
40
20
0
0
4
8
12
16
20
24
28
32
TIME - MINUTES

FIGURE 14.

Run No.:	646	648
Charge (grains):	20	40
Simulant:	DMHP	DMHP
Nozzle:	16 - .039" holes	16 - .039" holes
Peak Pressure (psi):	5,200	10,800
<u>Time</u>		
1-1/2	31.5	48.4
2-1/2	43.6	50.1
4-1/2	45.7	46.6
6-1/2	44.6	47.8
8-1/2	45.8	46.2
10-1/2	45.1	47.4
12-1/2	46.0	51.5
14-1/2	44.7	46.1

COMPARATIVE TEST DATA

CORRESPONDS TO CURVES ON FIGURE 16

FIGURE 15

AIRCRAFT ARMAMENTS, Inc.

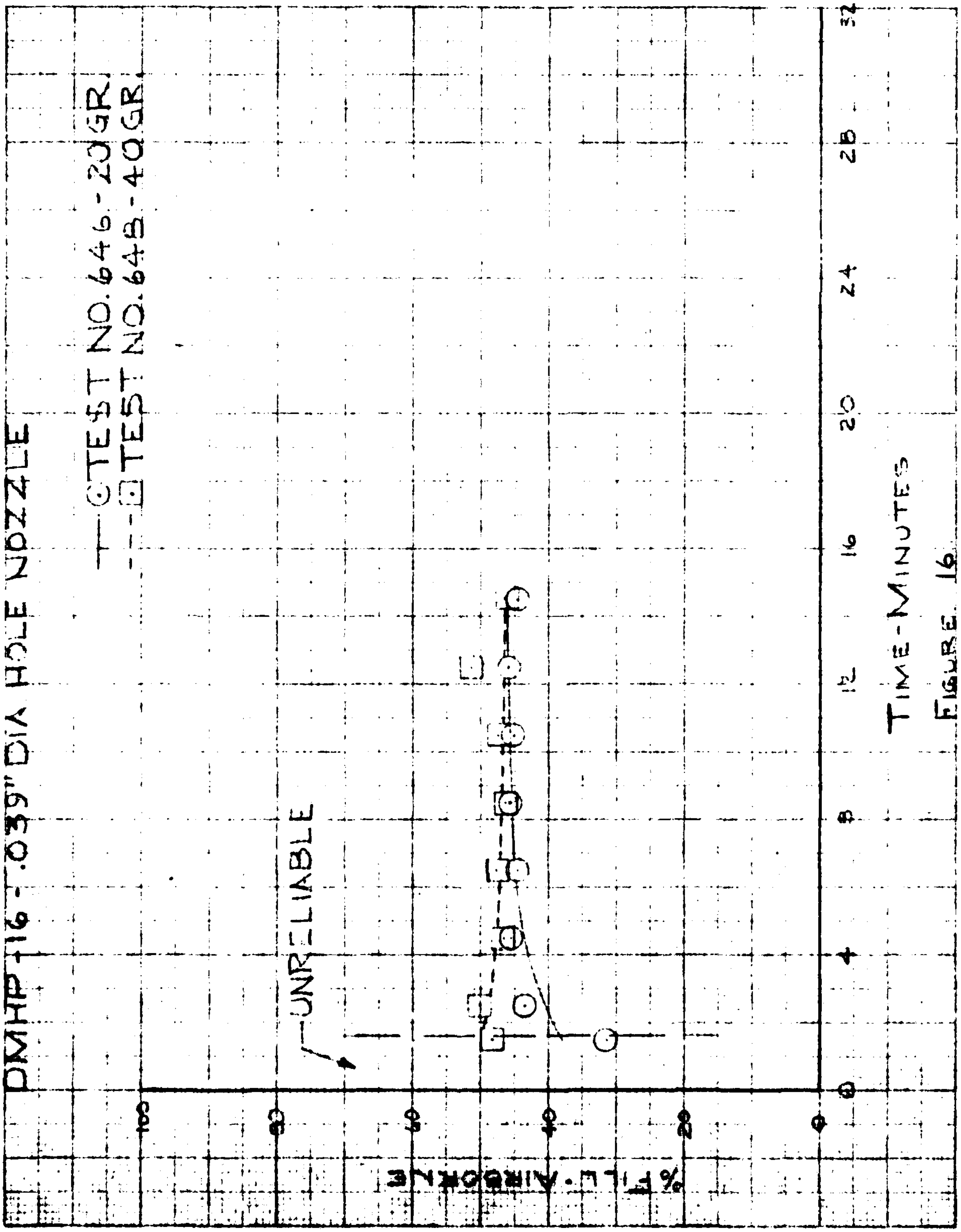


FIGURE 16

Run No.:	218	211	220
Charge (grains):	30	30	30
Simulant:	10% Egg Albumin	20% Egg Albumin	30% Egg Albumin
Nozzle:	16 - .039" holes	16 - .039" holes	16 - .039" holes
Peak Pressure (psi):	7,800	7,800	7,800
Time			
1/2	72.6	19.0	12.7
1-1/2	58.6	22.5	17.8
2-1/2	40.5	20.4	10.3
3-1/2	33.5	16.9	6.6
4-1/2	20.9	11.3	4.7
6-1/2	14.0	10.6	2.8
8-1/2	12.6	7.7	5.2
10-1/2	19.5	6.3	1.9
15-1/2	5.6	4.9	0.1
20-1/2	12.6	4.2	0.3
25-1/2	5.6	2.8	1.4
30-1/2	4.2	---	1.9

COMPARATIVE TEST DATA
CORRESPONDS TO CURVES ON FIGURE 18

FIGURE 17

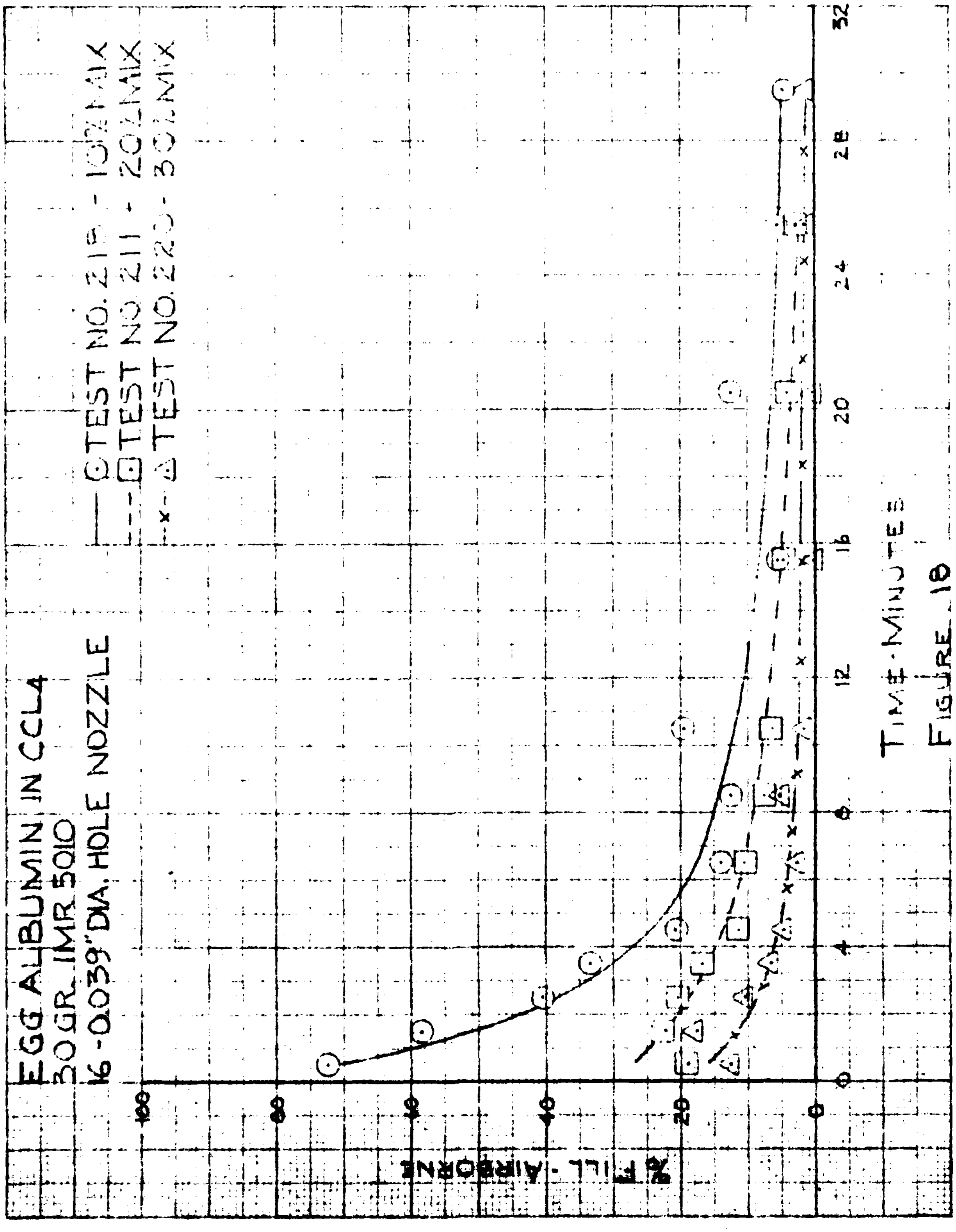

EGG ALBUMIN IN CCL4
30 GR. IMR 5010
16 - 0.039" DIA. HOLE NOZZLE
⊙ TEST NO. 219 - 10% MIX
⊡ TEST NO 211 - 20% MIX
△ TEST NO. 220 - 30% MIX
% FILL - AIRBORNE
100
80
60
40
20
0
4
8
12
16
20
24
28
32
TIME - MINUTES

FIGURE 18

The data for the second series of egg albumin shots with 20 grains of propellant is listed in Figure 19. These shots were again made with 10, 20 and 30 percent concentrations of egg albumin and the results plotted in Figure 20. In this series the percent fill-airborne of the 10 percent albumin shot was again about 150 percent higher than the 30 percent albumin shot. However, the 20 percent albumin shot gave percent fills-airborne which were slightly higher than the 10 percent albumin shot. An overlay of the two sets of curves indicates that the increase in charge had no significant effect on the percent fills-airborne except in the case of the 10 percent albumin shot. In this case there was approximately a 50 percent increase in the percent fill-airborne.

The fourth series of shots was made using BIS (2 ethylhexyl) Hydrogen Phosphite as the simulant. The data for this series fired with the 92-hole nozzle with 20 and 30 grains of IMR 5010 propellant, respectively, is given in Figure 21. The curves of the percent fills-airborne shown in Figure 22 indicate that there was no significant difference in the fills-airborne between the two propellant charges.

One other group of data in Figure 23 shows the results of three tests made with BIS as the simulant fired at a peak pressure of 35,000 psi. The first shot was made with the venturi orifice nozzle, the second with the 16-hole nozzle and the third with the 16-hole nozzle and hardware arranged to give a low capacity of simulant volume. Curves of these shots showing the respective percent fills-airborne are given in Figure 24. Of the three shots, the venturi

Run No.:	224	209	252
Charge (grains):	20	20	20
Simulant:	10% Egg Albumin	20% Egg Albumin	30% Egg Albumin
Nozzle:	16 - .039" holes	16 - .039" holes	16 - .039" holes
Peak Pressure (psi):	5,200	5,200	5,200
Time			
1/2	15.1	14.1	6.3
1-1/2	15.1	19.0	4.8
2-1/2	12.3	14.8	4.3
3-1/2	8.2	12.0	3.0
4-1/2	19.2	14.1	3.8
6-1/2	8.2	10.6	1.5
8-1/2	9.6	11.3	1.8
10-1/2	13.7	11.3	1.9
15-1/2	4.1	8.4	1.5
20-1/2	11.0	2.1	1.2
25-1/2	9.6	6.3	1.2
30-1/2	5.5	6.6	1.4

COMPARATIVE TEST DATA
CORRESPONDS TO CURVES ON FIGURE 20

FIGURE 19

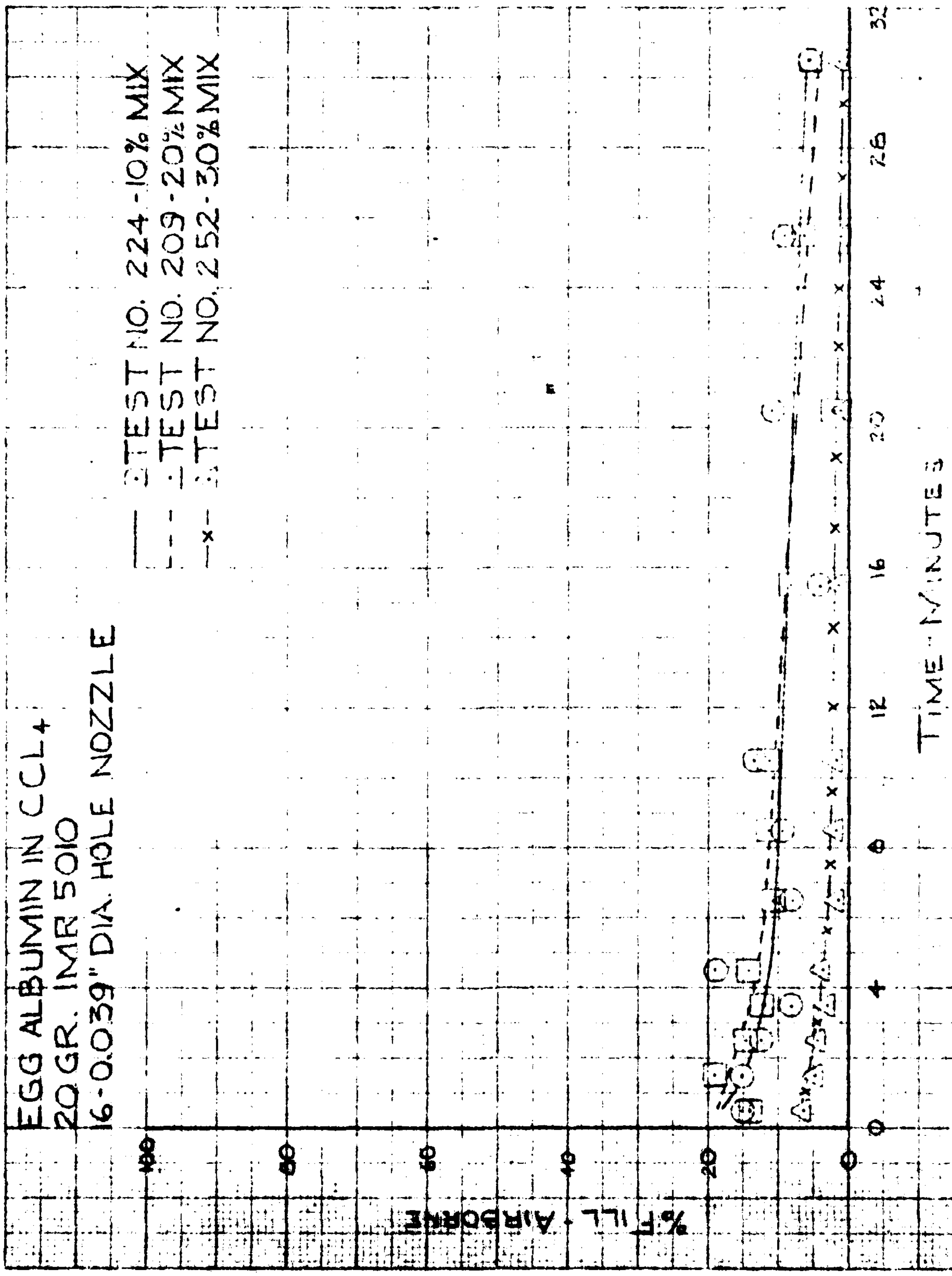

EGG ALBUMIN IN CCL4
20 GR. IMR 5010
16-0.039" DIA. HOLE NOZZLE
TEST NO. 224-10% MIX
TEST NO. 209-20% MIX
TEST NO. 252-30% MIX
TIME - MINUTES
% FILL - AIRBORNE
0
4
8
12
16
20
24
28
32
20
40
60
80
100

FIGURE 20

Run No.:	649	650
Charge (grains):	20	30
Simulant:	BIS	BIS
Nozzle:	92 - .016 holes	92 - .016 holes
Peak pressure (psi):	5,200	7,800
<u>Time</u>		
1/2	6.4	11.7
1-1/2	3.9	3.4
2-1/2	1.8	2.8
3-1/2	1.2	1.9
4-1/2	1.1	1.7
6-1/2	0.8	1.2
8-1/2	0.6	0.9
10-1/2	0.5	0.8
15-1/2	0.3	0.5
20-1/2	0.3	0.3
25-1/2	0.2	0.3
30-1/2	0.1	0.3

COMPARATIVE TEST DATA

CORRESPONDS TO CURVES ON FIGURE 22

FIGURE 21

AIRCRAFT ARMAMENTS, Inc.

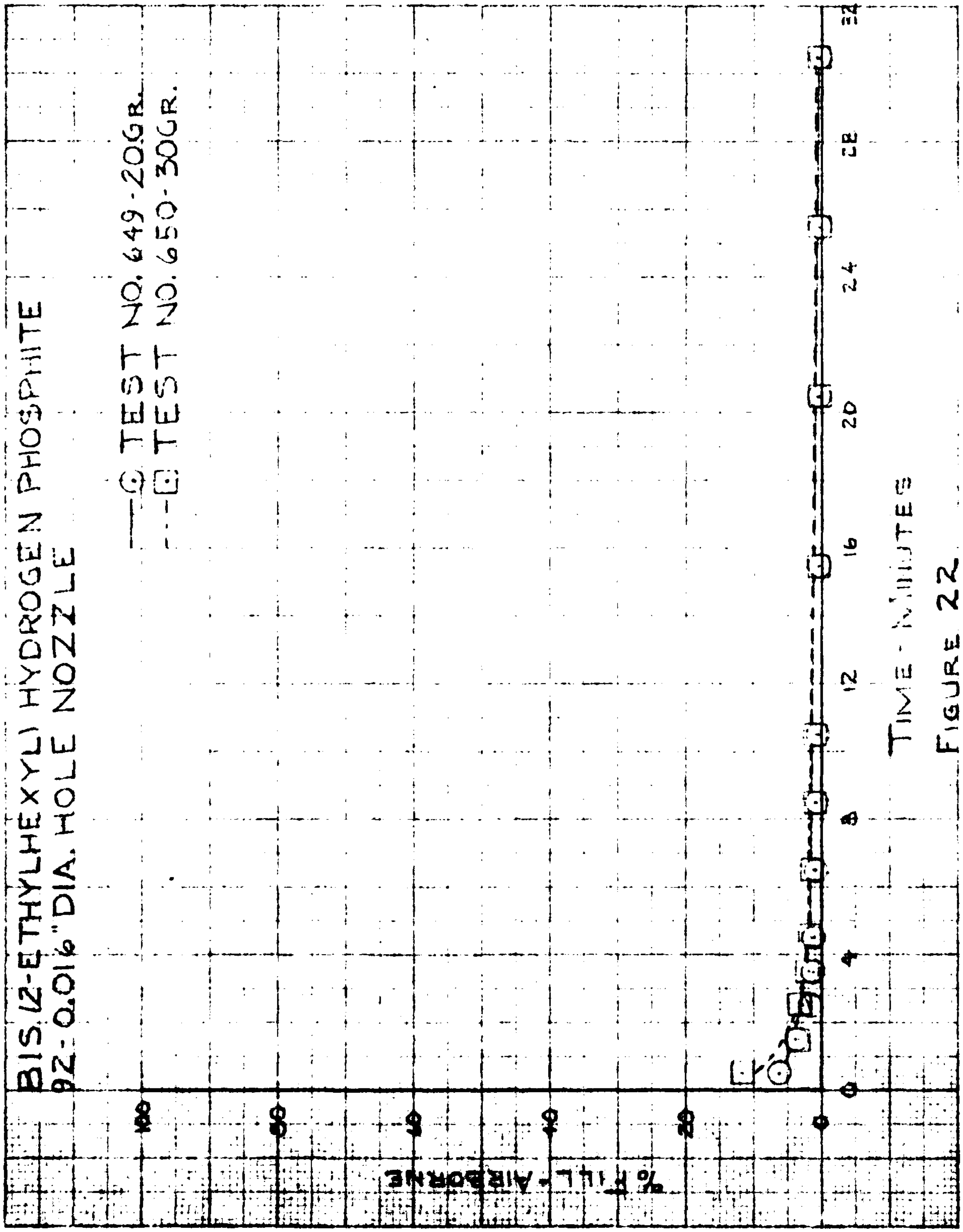


FIGURE 22

Run No.:	673	675	676
Charge (grains):	185	220	170
Simulant:	BIS	BIS	BIS (L.C.)
Nozzle:	Venturi	16 - .062 holes	16 - .062 holes
Peak Pressure (psi):	35,000	35,000	35,000
Time			
1/2	27.6	44.1	98.6
1-1/2	44.8	35.8	21.5
2-1/2	11.0	24.8	12.0
3-1/2	4.8	20.4	8.1
4-1/2	2.8	16.4	6.2
6-1/2	1.7	11.7	4.3
8-1/2	13.8	9.5	----
10-1/2	6.9	8.0	3.1
15-1/2	0.7	6.6	2.7
20-1/2	0.0	4.4	1.2
25-1/2	0.0	4.0	0.8
30-1/2	0.0	3.3	0.6

COMPARATIVE TEST DATA
CORRESPONDS TO CURVES ON FIGURE 24

FIGURE 23

AIRCRAFT ARMAMENTS, Inc.

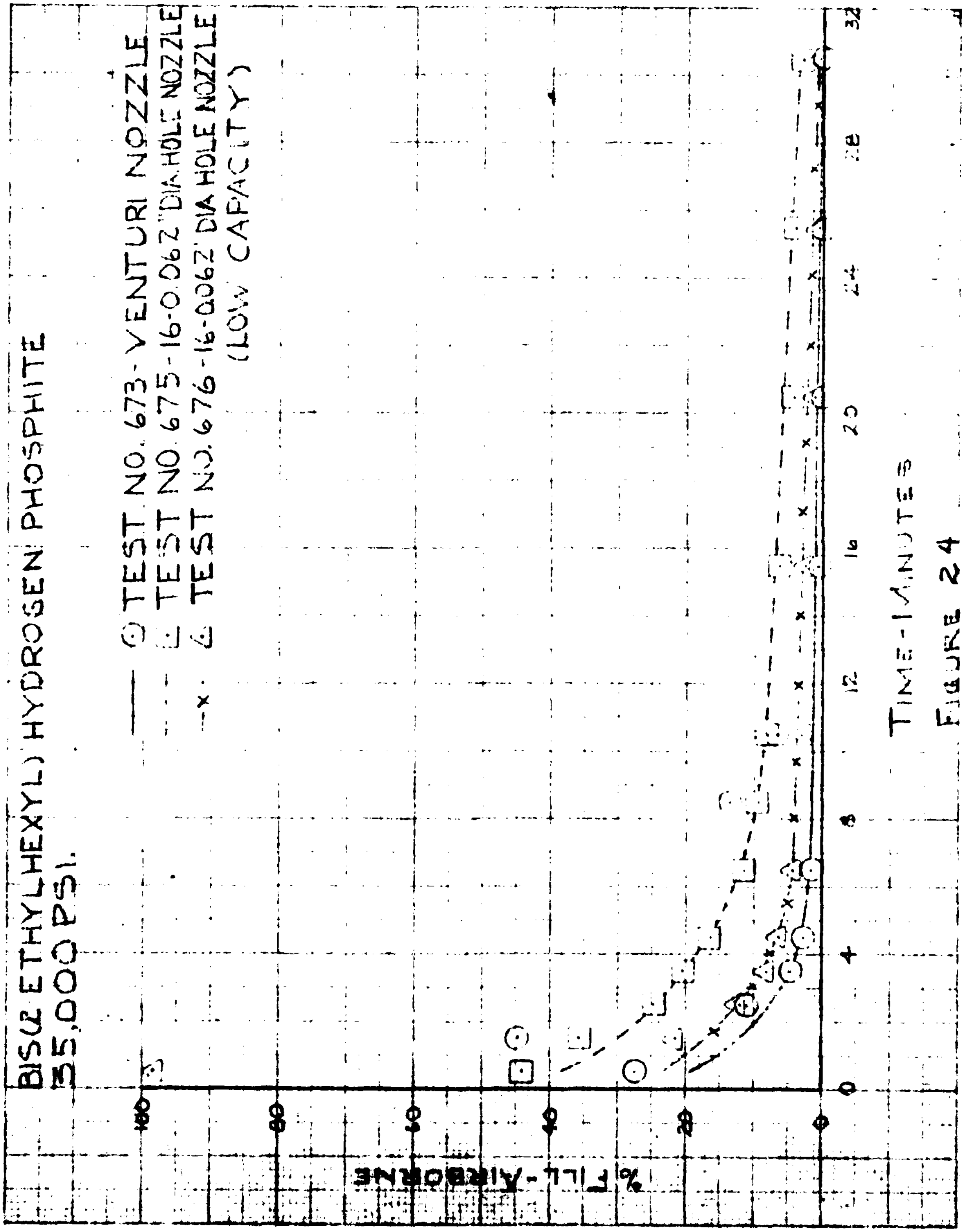


FIGURE 24

nozzle gave the poorest results. The low capacity shot gave percent fill-airborne data approximately 150 percent above results for the venturi nozzle. The standard 16-hole nozzle shot produced percent fill results about 175 percent above the low capacity unit.

The results of the dry powder shot are given in Figure 25. A plot of these results in Figure 26 shows that this unit gave a percent fill-airborne that compares very well with all previous egg albumin shots in a slurry. Because this unit was tested with nitrogen pressure less than half of the pressure used for tests at Aircraft Armaments, Inc., it is felt that higher yields can be obtained from this unit under proper conditions.

Analysis of all the curves indicates that for a particular series of shots an increase in peak pressure will produce higher percentages of fill-airborne. However, for a particular simulant fired at corresponding charges, little data is available for making comparisons between shots made with different nozzles. The only such data available is on the high pressure unit using BIS as the simulant and two low pressure shots with DMMP. In the case of the DMMP there was no significant gain in the percent fill-airborne between the 6 and 16 hole nozzles. In the results of the high pressure shots, the standard 16-hole nozzle gave fill percentages above the other two units tested, the low capacity unit and the venturi orifice nozzle.

In the slurry shots the most important variable in producing higher airborne yields was the percentage of egg albumin present in the slurry. Comparison of the two series of shots fired at different peak pressures shows there was no appreciable difference in yield except in one case, that of the 10 percent egg albumin shot.

AIRCRAFT ARMAMENTS, Inc.

Run No.:	371
Charge (grains):	30
Simulant	Dry Egg Albumin
200 psi Nitrogen	
<u>Time</u> (minutes)	
1	72.3
4	23.3
8	14.2
12	9.0
15-1/2	6.5
21	5.2
28	3.9

COMPARATIVE TEST DATA
CORRESPONDS TO CURVE IN FIGURE 26

FIGURE 25

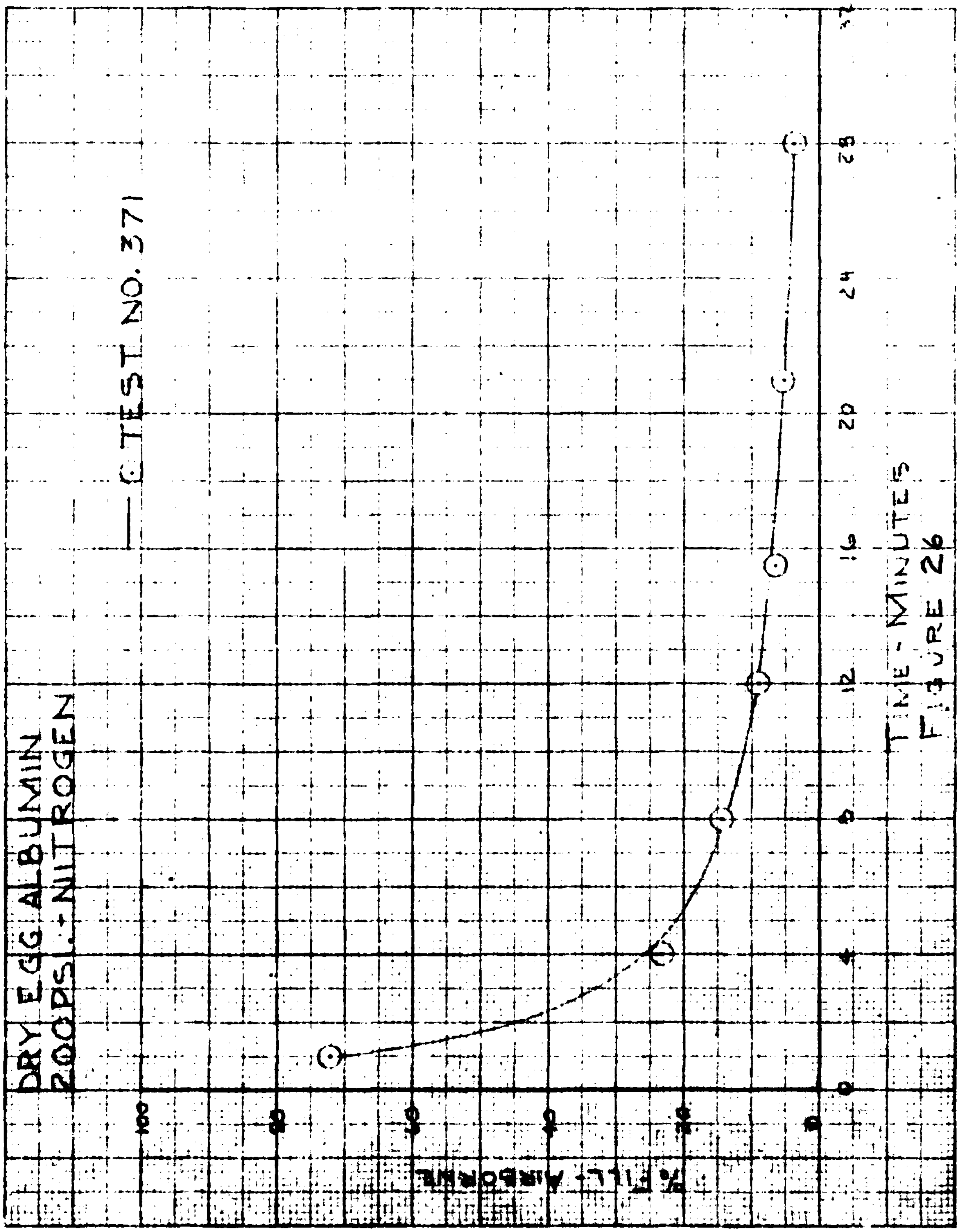

DRY EGG ALBUMIN
200PSI.-NITROGEN
⊙ TEST NO. 371
TIME - MINUTES
0
4
8
12
16
20
24
28
% FILL - AIRBORNE
0
20
40
60
80
100

FIGURE 26

High speed motion pictures, of tests made with the high pressure fixture, indicate that the cloud formations produced at these pressures is very tall, between 15 and 25 feet. This action could well be causing a very measureable portion of simulant to be deposited on the walls and ceiling of the test chamber. The unit has been set to fire diagonally across the chamber at an angle of about 30 degrees to the floor to minimize this problem. However, whenever foil sheets are placed in the chamber, some evidence of this impaction on the walls and ceiling is still noted.

Throughout testing on this program it was noted that an increase in pressure which in turn produced an increase in flow rate for a given nozzle configuration produced better results with regard to percent fill-airborne. These increases in flow rate produced corresponding decreases in stroke time for the various units tested. Throughout testing stroke times varied from 40 milliseconds down to about 4 milliseconds for shots made at the Army Chemical Center. However, stroke times of .6 seconds were obtained in the shots where the .010 inch diameter hole nozzle was used. Figure 27 is a tabulation of representative shots made at the Army Chemical Center for which corresponding time-pressure curves are shown in Figures 28, 29, 30, 31, 32, 33, 34, 35, 36 and 37.

The degree of volatility of the simulant appears to be one of the most important factors in determining the particle sizes produced and therefore the effectiveness of the unit to realize high percentages of fill-airborne. For example, the shots fired with DMHP at the relatively low pressures of the early test fixture gave percent fills-airborne, that were on the average 800

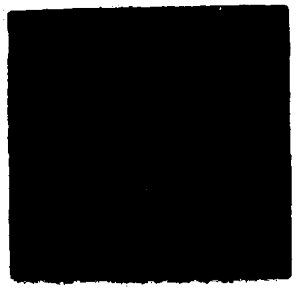
Shot No.	Charge (grains)	Simulant	Nozzle
1	35	DMHP	6 - .0625" dia. holes
2	37	DMHP	6 - .0625" dia. holes
3	20	DMHP	6 - .0625" dia. holes
4	30	DMHP	6 - .0625" dia. holes
5	40	DMHP	6 - .0625" dia. holes
6	20	DMHP	16 - .039" dia. holes
7	40	DMHP	16 - .039" dia. holes
8	20	10% Egg Albumin	16 - .039" dia. holes
9	20	15% Egg Albumin	16 - .039" dia. holes
10	20	20% Egg Albumin	16 - .039" dia. holes
11	20	30% Egg Albumin	16 - .039" dia. holes
12	30	10% Egg Albumin	16 - .039" dia. holes
13	30	15% Egg Albumin	16 - .039" dia. holes
14	30	20% Egg Albumin	16 - .039" dia. holes
15	30	30% Egg Albumin	16 - .039" dia. holes
16	20	BIS	92 - .016" dia. holes
17	30	BIS	92 - .016" dia. holes
18	185	BIS	Venturi Nozzle
19	220	BIS	16 - .0625" dia. holes
20	170	BIS (low capacity)	16 - .0625" dia. holes

TABULATION OF REPRESENTATIVE TIME-PRESSURE CURVES

FIGURE 27

AIRCRAFT ARMAMENTS, Inc.

Shot #1



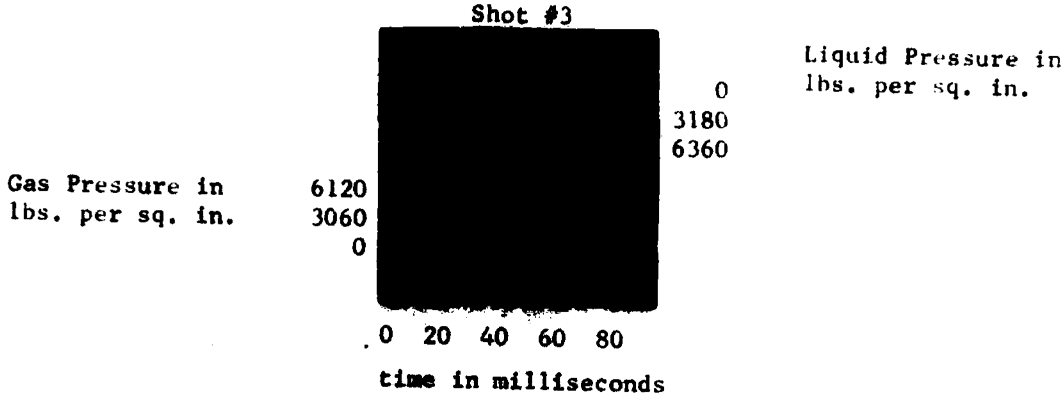
Shot #2

TIME-PRESSURE CURVES

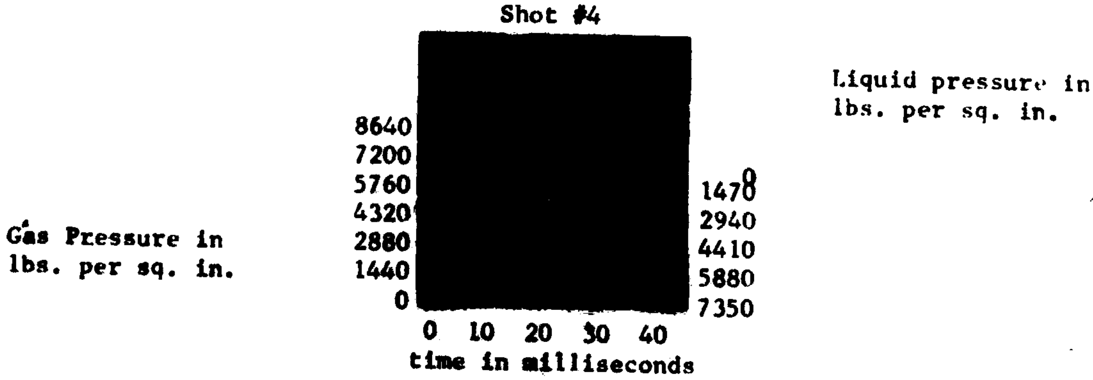
FIGURE 28

600949

Shot #3



Shot #4

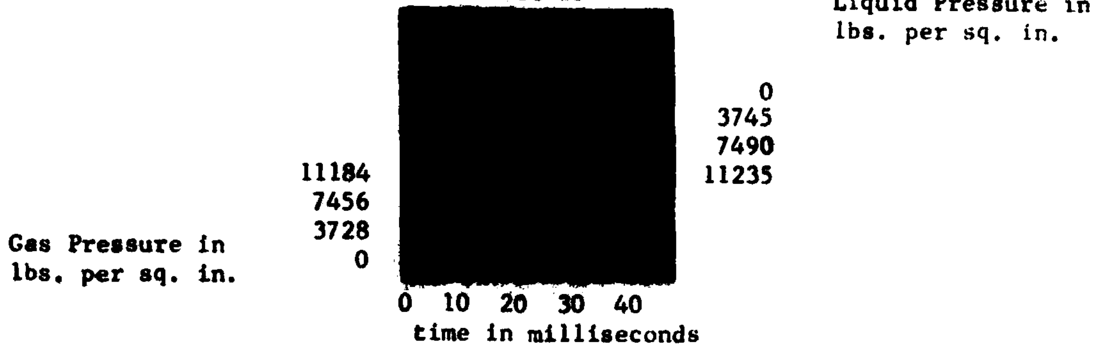


TIME-PRESSURE CURVES

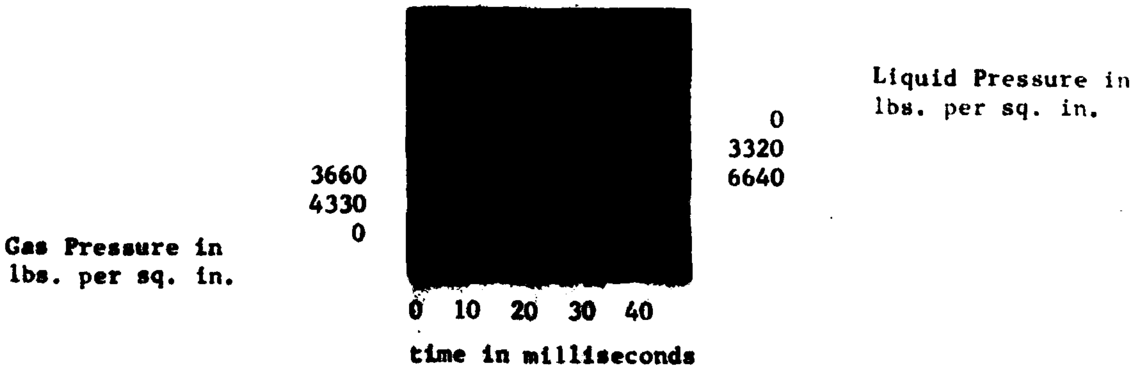
FIGURE 29

600949

Shot #5



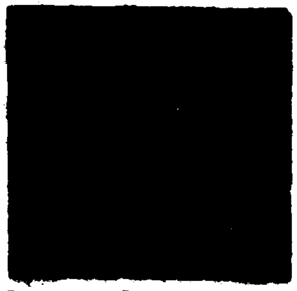
Shot #6



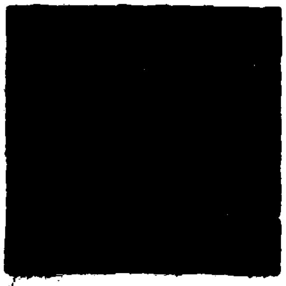
TIME-PRESSURE CURVES

FIGURE 30

Shot #7

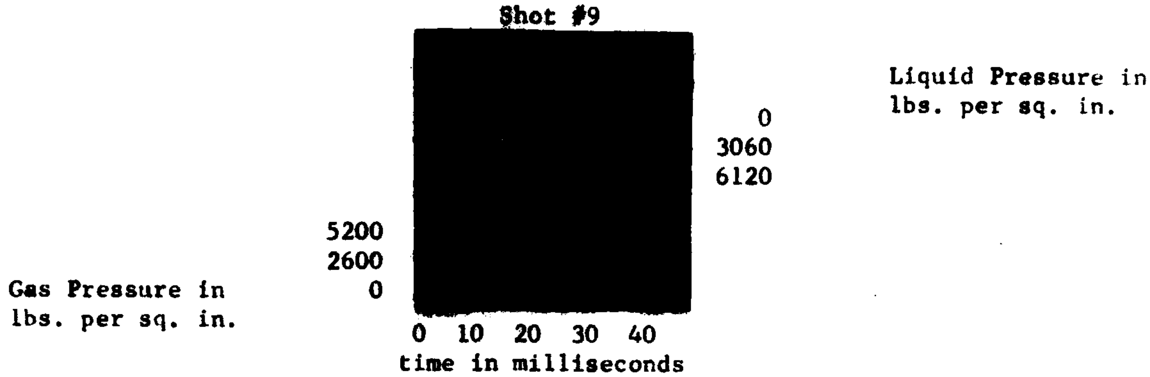


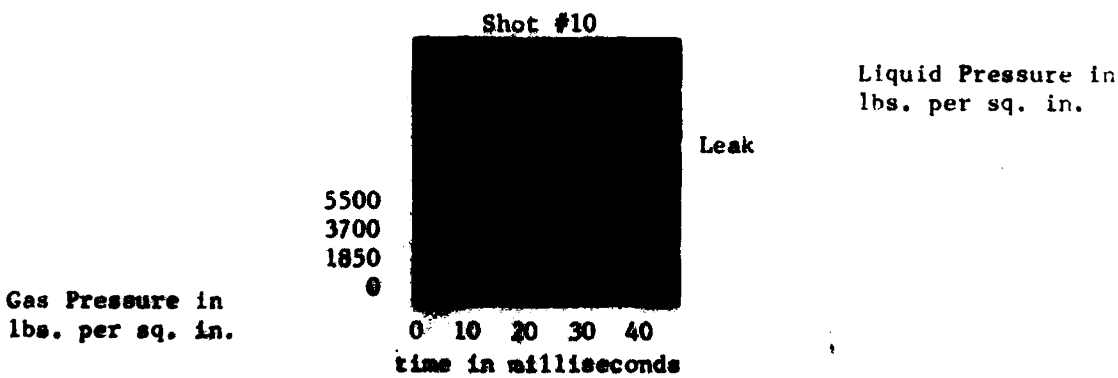
Shot #8



TIME-PRESSURE CURVES

FIGURE 31

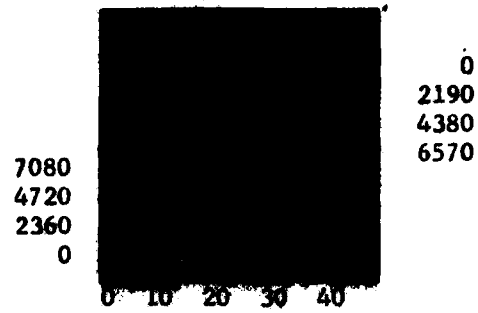




TIME-PRESSURE CURVES

FIGURE 32

Shot #11

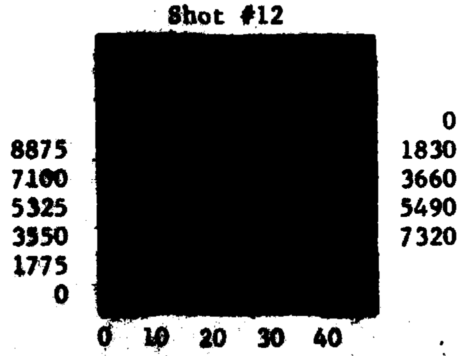


Liquid Pressure in lbs. per sq. in.

Gas Pressure in lbs. per sq. in.

time in milliseconds

Shot #12



Liquid Pressure in lbs. per sq. in.

Gas Pressure in lbs. per sq. in.

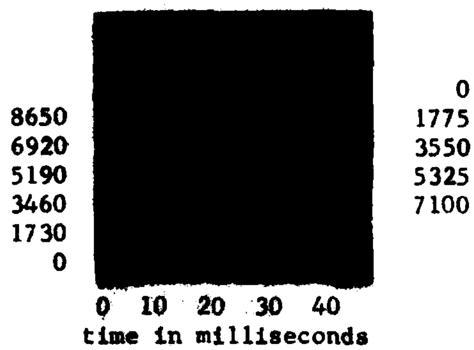
time in milliseconds

TIME-PRESSURE CURVES

FIGURE 33

600769

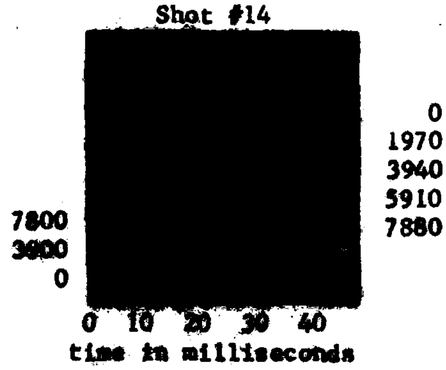
Shot #13



Liquid Pressure in lbs. per sq. in.

Gas Pressure in lbs. per sq. in.

Shot #14



Liquid Pressure in lbs. per sq. in.

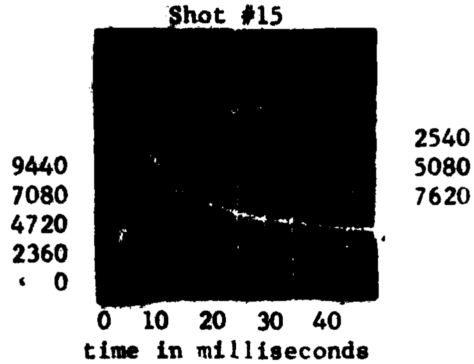
Gas Pressure in lbs. per sq. in.

TIME-PRESSURE CURVES

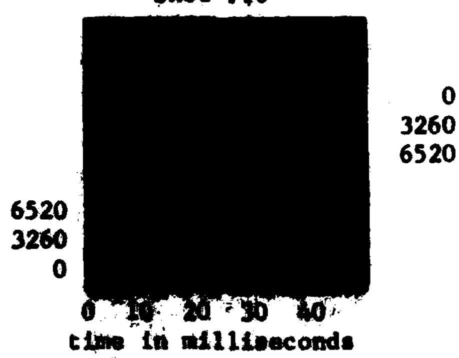
FIGURE 34

6009 49

Shot #15



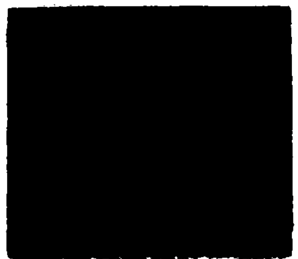
Shot #16



TIME-PRESSURE CURVES

FIGURE 35

Shot #17

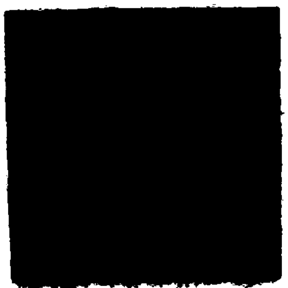


Shot #18

TIME-PRESSURE CURVES

FIGURE 36

Shot #19



Liquid Pressure in lbs. per sq. in.: 0, 16000, 32000, 48000

Gas Pressure in lbs. per sq. in.: 47700, 31800, 15900, 0

0 10 20 30 40
time in milliseconds

Shot #20

Liquid Pressure in lbs. per sq. in.: 0, 16000, 32000, 48000

Gas Pressure in lbs. per sq. in.: 47700, 31800, 15900, 0

0 10 20 30 40
time in milliseconds

TIME-PRESSURE CURVES

FIGURE 37

percent above the best of the high pressure shots made with BIS as the simulant. The DMHP shots also yielded percentage fills-airborne averaging approximately 350 percent higher than shots with slurries of egg albumin in carbon tetrachloride. These results tend to substantiate our basic premise that for a given nozzle configuration the particles formed initially, of any simulant, are of the same size in microns (MMD). However, the higher evaporation rate of the more volatile simulants is responsible for the rapid breakdown into small particles, thereby producing higher vapor yields for long time intervals.

A comparison of Figures 14 and 16, using DMHP as the simulant, shows practically no difference in the percent fills-airborne between the 6 and 16 hole nozzles fired with propellant charges producing the same peak pressures. The orifice areas of these two nozzles have also been set equal to each other to maintain an equal flow rate and stream velocity between them. Therefore, the only variables which could have produced higher percentages of fill-airborne were the number and size of holes. Because the higher yields that it was felt the smaller holes would produce were not realized, an explanation was sought. Studies of cloud formation between the two nozzles showed that the stream velocities of the 16 hole nozzle were below those of the 6 hole nozzle. This, then, showed that the lower discharge coefficient related with more orifices of smaller cross section was responsible for an actual decrease in flow rate and stream velocity.

IV. CONCLUSIONS AND RECOMMENDATIONS

The data which has been supplied by the Army Chemical Center has been carefully studied and combined with results of corresponding tests conducted at the Aircraft Armaments, Inc. test facilities to determine the dissemination characteristics of the various units.

Analysis of the data collected shows that, by far, the best results were obtained with the volatile simulant, DMHP. This is due to the fact that the more volatile simulants are able to vaporize much more rapidly than non-volatiles once they are released into the atmosphere.

The increases in charge, hence peak pressure, for several of the DMHP shots gave percent fills-airborne that were significantly higher, approximately 15 percent for each increase of 10 grains of propellant. These results are explained by the higher stream velocities produced which, as was explained earlier, is a major factor in the production of small particles in the collision between liquid stream and air. Although no tests of the high pressure fixture were made at the Army Chemical Center using DMHP as the simulant, there is every reason to believe that the pressures produced would give results which would approach 100 percent total airborne yield.

Tests on DMHP to compare results obtained from firing corresponding shots through different nozzles showed no appreciable gain in yield from nozzles with more holes of a smaller diameter.

In the egg albumin slurry shots, increases in charge and decreases in egg albumin percentage in the slurry both led to higher percentages of fill-airborne. However, the results of these tests were in the range well below desired results. For this reason, the large percentile gains between corresponding shots has little meaning.

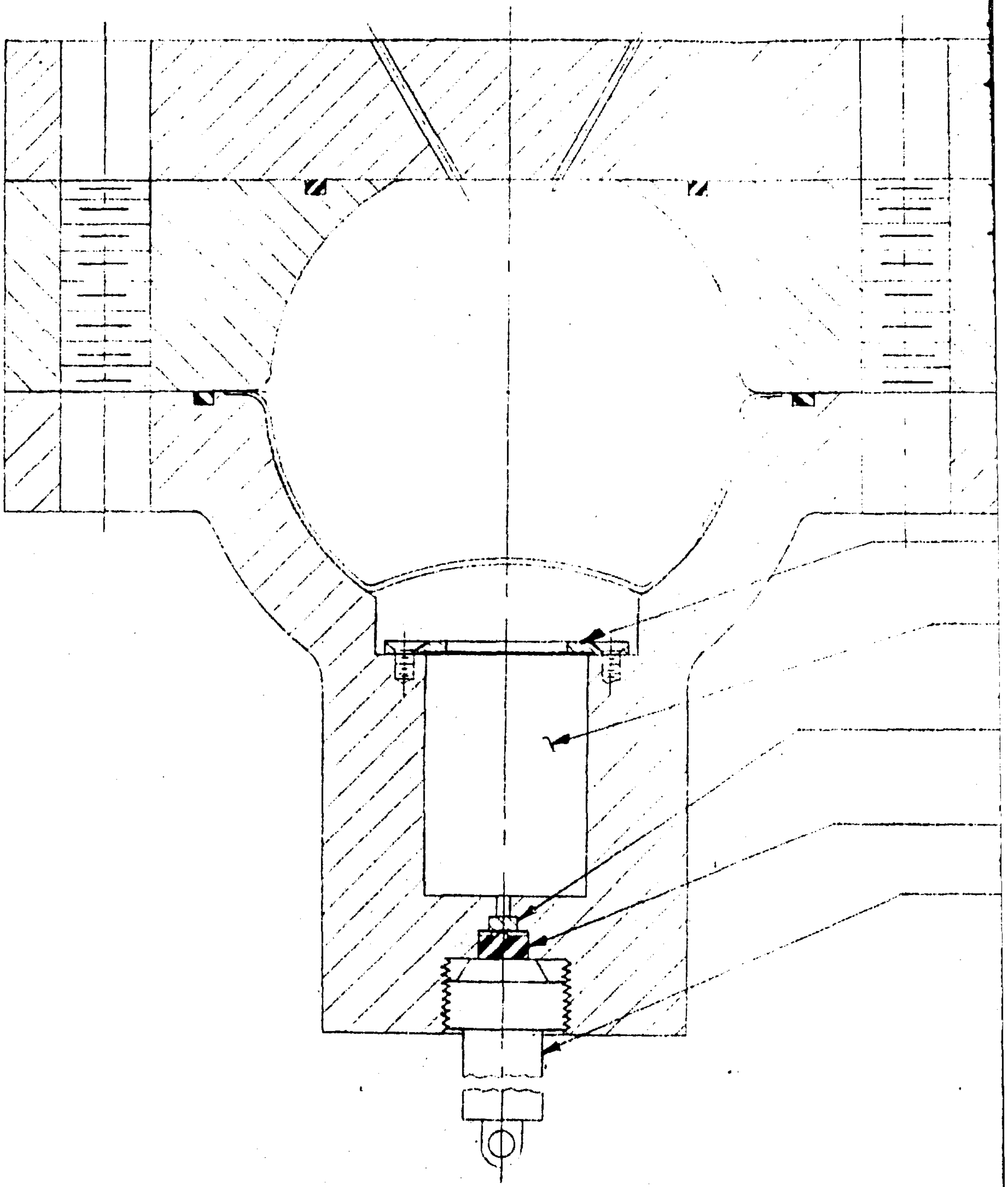
The high pressure fixture, tested only with BIS as the simulant, did not produce particles in the range desired as shown by the results on yield from Army Chemical Center tests. However, it is believed that the increased pressures and stream velocities of this unit may be responsible for a high degree of impaction of simulant on the walls and ceiling of the chamber. The unit may, therefore, produce the desired results if tested in the field or in a chamber more nearly fitting the configuration of the cloud produced by this unit.

In order to determine conclusively the ability of Telecartridge cup sealed dispensers to produce small aerosol particles it is felt by this contractor that further tests should be conducted. These tests would involve the use of a spherical high pressure fixture similar to that illustrated in Figure 38.

Among the things to be investigated in these tests would be further studies of nozzle configuration. To be considered are single small hole nozzles, with holes on the order of .010 of an inch in diameter, nozzles with varying numbers and patterns of these small holes, a nozzle incorporating an aerator device to force a jet of air into the liquid stream to aid in the production of small aerosol particles, and other designs.

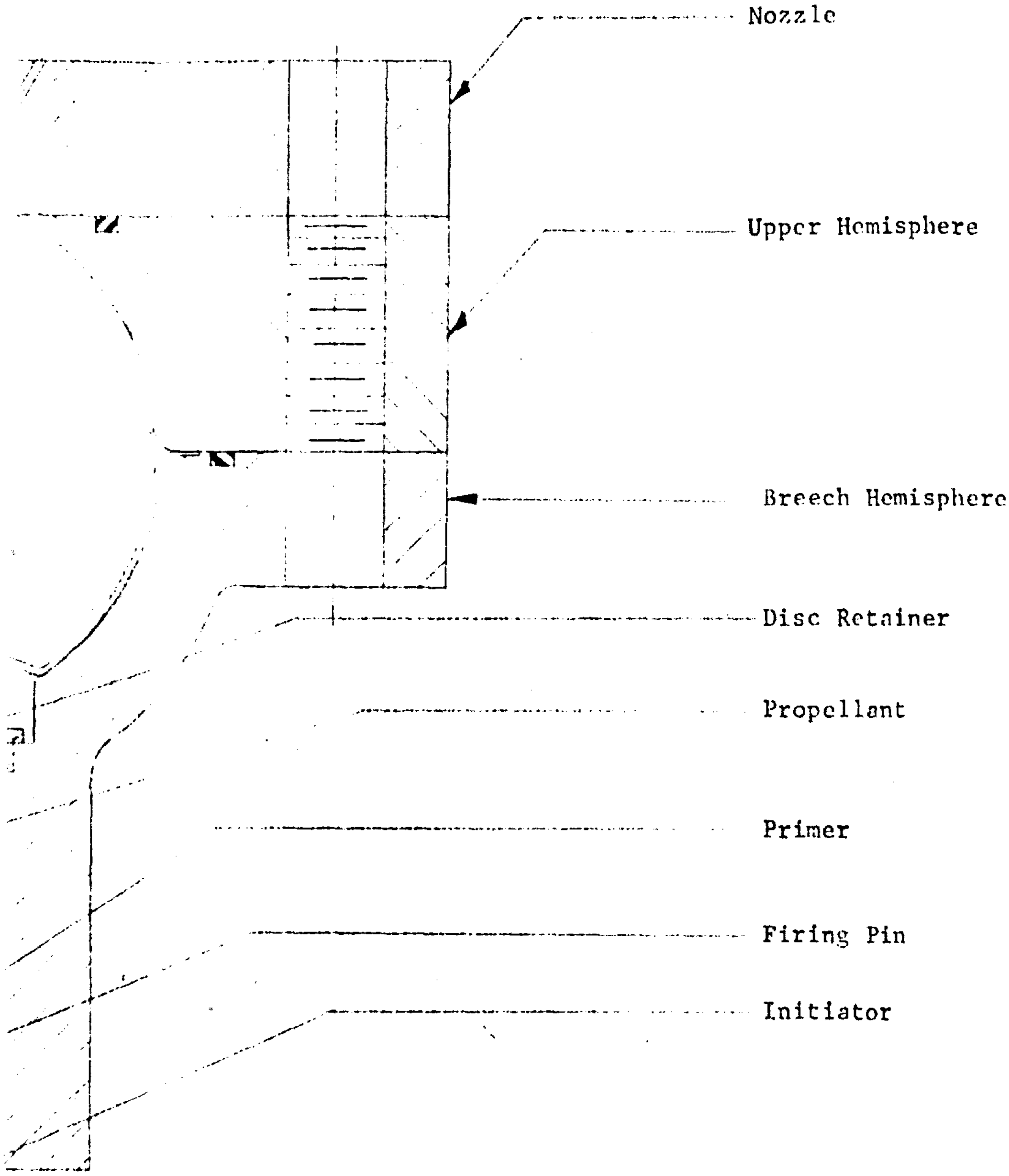
It is proposed that additional investigation be directed toward (1) non-volatile fluid, (2) volatile fluid, (3) dry powder, (4) dry powder - volatile fluid suspension and (5) dry powder - volatile fluid solution.

AIRCRAFT ARMAMENTS, Inc.



SPHERICAL TELECARTRIDGE CUP SEA

FIGURE 38



HERICAL TELECARTRIDGE CUP SEALED TEST FIXTURE

FIGURE 38

2

Among other parameters to be investigated it is also felt that some tests should be made experimenting with different propellants to produce a burning rate which would give the best rise to peak pressure and the slowest rate of pressure decay. This higher average pressure would mean that a larger percentage of the simulant would be expended through the nozzle at a higher pressure. This would give rise to higher stream velocities, for given nozzles, which has been shown to be the most important factor in producing small particles. It is further felt that this testing be done with simulants of the non-volatile category.